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FR–II Broad Absorption Line Quasars and the Life Cycle of Quasars

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ABSTRACT

By combining the Sloan Digitized Sky Survey Third Data Release quasar list with the VLA FIRST survey, we have identified five objects having both broad absorption lines in their optical spectra and FR–II radio morphologies. We identify an additional example of this class from the FIRST Bright Quasar Survey, J1408+3054. Including the original FR-II–BAL object, J1016+5209, brings the number of such objects to eight. These quasars are relatively rare; finding this small handful has required the 45,000-large quasar sample of SDSS. The FR-II–BAL quasars exhibit a significant anti-correlation between radio-loudness and the strength of the BAL features. This is easily accounted for by the evolutionary picture in which quasars emerge from cocoons of BAL-producing material which stifle the development of radio jets and lobes. There is no such simple explanation for the observed properties of FR-II–BALs in the unification-by-orientation model of quasars. The rarity of the FR-II–BAL class implies that the two phases do not coexist for very long in a single quasar, perhaps less than 10^5 years, with the combined FR-II, high ionization broad absorption phase being even shorter by another factor of 10 or more.

Subject headings: quasars: absorption lines; quasars: general

1. Introduction

Broad absorption line (BAL) quasars have been recognized as an important subclass of quasar for at least 20 years. Our understanding of the phenomenon has evolved with

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time, both in the variety of BAL types as well as their frequency of occurrence (Hall et al 2002). The growth in understanding has been fueled by extensive quasar surveys which have expanded the phase space occupied by BAL QSOs. Until the late 1990s, it was widely accepted that a quasar could not be both radio-loud and exhibit BALs (Stocke et al. 1992), but then the VLA FIRST survey (Becker et al. 1995; White et al. 1997) found significant numbers of radio-loud BALs (Becker et al. 2000). In retrospect, it is not surprising that the first large area, high sensitivity radio sky survey would greatly expand our understanding of quasar radio properties. The discovery of FIRST J1016+5209 proved that BAL QSOs could even exist even in classic FR2 radio sources (Gregg et al. 2000).

Approximately one of every six quasars has BALs in its optical spectrum (see discussion in Reichard et al. 2003), while a few percent of all optically selected quasars are Fanaroff–Riley Class II radio sources (FR–II; Fanaroff & Riley 1974). If these two quasar types occur independently, then, given today’s cataloged population of $\sim 10^5$ quasars, there should be several hundred which exhibit both FR–II and BAL properties. To date, however, there are just three published examples of FR–II–BALs: in addition to J1016+5209 there is the somewhat doubtful and more modest example of PKS 1004+13 (Wills, Brandt, & Laor 1999) and the long-overlooked LBQS 1138-0126 (Brotherton et al. 2002). So FR–II’s appear to be significantly underrepresented among BALs.

To better quantify this effect, we have examined the FIRST radio properties of the $\sim 45,000$ quasars in the Sloan Digital Sky Survey (SDSS) Third Data Release (DR3) sample (Abazajian et al. 2004). Full details are presented in a companion paper (deVries et al. 2005). Briefly, we searched the VLA FIRST images down to a 3σ ($\sim 0.5\text{mJy}$) level for core emission from the DR3 quasar sample, and searched the vicinity of each SDSS quasar for associated, extended emission from radio lobes. This procedure found that up to $\sim 2.8\%$ of the SDSS quasars have radio emission consistent with FR–II morphology. Of these, we find five which also have BAL features in their optical spectra, four of which are new examples of FR–II–BAL quasars. Including another object, J1408+3054, from the FIRST Bright Quasar Survey (FBQS, Gregg et al. 1996), brings the total of new objects to six, and quadruples the known sample of FR–II–BAL quasars (excluding PKS 1004+13), permitting some analysis of their properties as a class.

2. Constructing the Sample

The SDSS has created a spectroscopic survey of quasars selected from a five color optical image of the sky. The SDSS survey spectra cover $\lambda\lambda 3820 - 9200\text{\AA}$. Of the 44,982 SDSS DR3 quasars, 33,542 (74.6%) are in the redshift interval 0.40 to 2.20, permitting unambiguous

identification of low ionization BAL quasars (“LoBALs”) from their blueshifted broad Mg II absorption. Only 15,484 (34.4%) of all DR3 quasars are in the redshift interval 1.7 to 4.9 appropriate for identifying high ionization BAL quasars (“HiBALs”) from C IV absorption.

We visually inspected the DR3 release spectra of the SDSS quasars that we identified as likely FIRST FR–II radio sources, flagging potential BAL quasars based on the presence of absorption to the blue of either C IV or Mg II. The amount of broad absorption was quantified using the “balnicity” index of Weymann et al. (1991). Six FR–II quasars with positive balnicity were identified, 4 LoBALs and 2 HiBAL. One of the quasars is in the rare “FeLoBAL” class exhibiting additional absorption from metastable excited states of FeII and FeIII (Wampler, Chugai, & Petitjean 1995), similar to FIRST J1556+3517, the original radio-loud BAL quasar (Becker et al. 1997). In this sample, we have rediscovered the previously-identified FR–II LoBAL, LBQS 1138-0126 (Brotherton et al. 2002).

To this set we add another object, J1408+3054 from the FIRST Bright Quasar Survey (FBQS, Gregg et al. 1996). This object was mis-identified in the early results of the FBQS as a magnetic white dwarf (Becker et al. 1996). High signal-to-noise observations extending the optical spectral coverage to the ground ultraviolet revealed strong broad emission which we identified as C III], showing J1408+3054 to be an unusual BAL quasar at a redshift of 0.84 (White et al. 2000); this object is not yet in the SDSS coverage area. The SDSS has since found several very similar objects whose unusual spectra result from heavily overlapping BAL troughs (Hall et al. 2002). The FBQS object is distinguished from the SDSS counterparts by a DC offset of its optical spectrum above zero, meaning that the BAL troughs are not completely black. While often interpreted as a sign of partial covering in BAL quasars, the non-zero trough flux is in this case perhaps associated with the radio emission.

Including J1016+5209 (imaged by SDSS but not targeted for spectroscopy), there are now eight FR-II–BAL quasars, some requiring confirmation (see below). We summarize their observed and derived properties in Tables 1 and 2.

3. Quantifying the Radio Properties

The left side of Figure 1a-c shows the r -band images of the six newly-identified SDSS FR-II–BAL quasars; over-plotted are FIRST radio contours. Similar images of J1016+5209 (Gregg et al. 2000) and LBQS 1138-0126 (Brotherton et al. 2002) can be found in their respective discovery papers. The vertical bar in each panel represents the angular size subtended by 100 kpc (roughly $12''$) at the redshift of each quasar, giving some indication of the scale of the radio structures. Five panels are shown at the same angular scale; the

lower redshift J1408+3054 is zoomed out by a factor of two. The peak lobe-to-lobe physical sizes and the core-to-lobe ratios are typical of large FR–II structures (Table 2). J0043-0015, J0148-0819, and J1447+5203 are FR–II objects beyond doubt. J1457+0426 is a weaker source, but the radio image leaves little doubt that it is an FR–II. J0952+0257 also must be considered an excellent candidate FR–II but in need of further confirmation; even though the lobes are suggestively oriented, there is little evidence of any connection between the lobes and the central source. While this paper was undergoing revisions, Zhou et al. (2005) independently identified J0043-0015 and J0148-0819 as SDSS BAL QSOs with extended FIRST radio morphology.

The radio data for J1408+3054 perhaps leaves room to doubt its classification as an FR–II because there is no connection between the lobes and core and because of its large extent, 1.7 Mpc, though it is still well within the bounds of known FR–II sizes which range up to ~ 6 Mpc for the giant radio source 3C236. In their analysis of FR–II sources in the FIRST survey, de Vries et al. give this source a roughly 50–50 chance of being an FR–II. The 325MHz low resolution ($1'$) WENSS survey (Rengelink et al. 1997) detects the southwest source at a level of 88 mJy, but does not detect the other two components. If the lobes had the same spectral index, then WENSS should find the other at 35 mJy, well above the 15-20mJy (5σ) detection limit; this unfortunately is not conclusive for or against the FR–II nature of this object. Favoring the FR–II interpretation, however, the core and lobes are co-linear, the lobes are extended while the core is a point source, and one of the lobes points directly back to the quasar. Deeper, lower frequency radio observations could bolster the uncertain FR–II identifications by providing evidence of core-lobe connections and spectral indices.

Table 1 lists the core+lobe NVSS catalog (Condon et al. 1998) 1.4 GHz flux for each object in our sample. Following Stocke et al. (1992, eqns 1 – 3), we have computed the radio-loudness parameter, R^* , the ratio of 5 GHz radio to 2500Å optical flux. We assume a radio spectral index $\alpha = -1$ to correct the 1.4 GHz radio fluxes to 5 GHz, and convert g to Johnson B using the relation $B = g + 0.47(g - r) + 0.17$ (Smith et al 2002). The dividing line between radio-loud and quiet is usually taken to be +1, so all of these FR–II–BALs are radio-loud (Table 1). BAL quasars, LoBALs in particular, are known to have higher intrinsic reddenings than ordinary quasars (Sprayberry & Foltz 1992; Becker et al. 2000). We make a first first-order correction for reddening in calculating R^* and M_g by using the observed z magnitude and the mean $g - z$ color (typically 0.1 to 0.4) for quasars at their respective redshifts (Richards et al. 2003) to determine a relatively unreddened g . The advantage of this approach over detailed spectral fitting to quasar templates to determine reddening is that it is much simpler and, given the uncertainties in quasar reddening laws and the difficulties of fitting BAL-ridden continua, perhaps just as reliable. The uncorrected and corrected R^* and

M_g are listed in Table 2. Even after correction, all of the quasars are still radio-loud. The largest extinction correction is for J1457+0426, the FeLoBAL, amounting to 2.5 magnitudes in A_g .

4. Quantifying the Broad Absorption

Plotted in the right panels of Figure 1a-c are the SDSS spectra for four of the quasars. C IV in J0952-0257 was just below the blue wavelength limit of the SDSS spectra, so we obtained a new spectrum of this object using the Kast Spectrograph on the Lick Observatory 3m telescope in 2005, January. This spectrum extends to 3300Å and reveals a very strong C IV BAL feature. The spectrum of J1408+3054 was also obtained with the Kast Spectrograph in 1997, October. The Kast spectra have a resolution of 6Å and were obtained in photometric conditions.

The balnicity index was measured from C IV for J0043-0015, J0148-0819, J0952+0257, and J1447+5203; for the lower redshift objects J1408+3054 and J1457+0426, we are forced to use the Mg II feature. Because the C IV broad absorption is usually greater, (Figure 1a-c), the Mg II balnicities can be considered lower limits. To measure the balnicity index properly, the spectra must first be flattened and normalized using a fit to the continuum, so the balnicity is sensitive to the placement of the continuum and the order of the fit, but in no way is it possible to force any of these objects to have an index even close to zero. The balnicity index is designed to be a very conservative test for deciding whether quasars have broad, high velocity outflows features, so these objects, all with balnicities $\gtrsim 1000$, are unambiguous BAL quasars (Table 2). The spectral regions used in measuring the balnicity index is shown in Figure 2 for each of the seven new objects.

The FeLoBAL J1457+0426 presents a complication: its Mg II broad absorption has a substantial contribution from *narrow* absorption by metastable excited states of FeII (Hazard et al. 1987; Becker et al. 1997). Including this absorption, J1457+0426 has the largest raw balnicity index (9205) of the 8 objects in the sample. To estimate the contribution to the BI from FeII, we interpolate over the affected wavelength regions (Wampler et al. 1995), shown in grey in Figure 2; this reduces the balnicity index by a factor of 2.5, to 3596. This is possibly an over-correction because there may be additional Mg II broad absorption in these intervals; modeling of the Fe contribution with higher dispersion spectra could quantify this more accurately. Further, it is not clear whether this correction is even called for as the nature of the narrow FeII absorption and its relation to the BAL features is not understood. We consider both values for J1457+0426 in the discussion below.

5. Discussion

Although it was long believed that radio-loudness and broad absorption features were mutually exclusive quasar properties (e.g., Stocke et al. 1992), it has been known for many years that BAL quasars exhibit radio emission at least as frequently as ordinary quasars (Barvainis & Lonsdale 1997; Becker et al. 2000). With the advent of the FIRST survey and a large radio-selected quasar sample, the existence of radio-loud BALs was established (Becker et al. 1997; 2000). Shortly thereafter, the first object with both FR-II and BAL properties was discovered (Gregg et al. 2000). The present set of eight FR-II–BAL quasars, culled mainly from the extensive SDSS quasar catalog, shows that FR-II–BAL quasars, while still relatively rare, constitute a subclass of quasars and provide an opportunity learn about quasar life cycles and evolution. The early belief that radio-loudness, and especially FR-II morphology, could not coexist with broad absorption in a quasar can be ascribed to small number statistics.

Even with 8 objects, FR-II–BAL quasars are still under-represented by a large margin in the general quasar population. The expected number is difficult to compute accurately for numerous reasons including uncertainties of quasar evolution by type, possible selection effects against BAL quasars in SDSS, and the completeness of the SDSS spectroscopy as a function of quasar redshift and type. About 16% of quasars have BAL features, divided roughly 8:1 between HiBAL and LoBAL objects (Hewitt et al. 1995; Becker et al. 2000; Reichard et al. 2003), while our study of the radio morphology of SDSS quasars finds that up to $\sim 2.8\%$ may be FR-II sources (de Vries et al. 2005). Thus in the interval $1.7 < z < 3.6$ where SDSS can detect C IV, we expect to see ~ 70 FR-II–HiBAL quasars, assuming radio and BAL properties to be independent and no change in numbers with redshift, but find only 2 (three counting J1016+5209, which is not in the SDSS spectroscopic sample). In the interval $0.4 < z < 2.2$, where Mg II is used to identify BAL behavior in the SDSS spectra, we expect to find about 20 LoBAL objects and see just 5 (J1408+3054 is not in the SDSS DR3 coverage). All quasars with Mg II BAL features also have C IV BALs, but the reverse is not true, so because of the limited redshift range over which HiBAL quasars can be detected in SDSS spectra, FR-II–HiBAL sources with $z < 1.7$ will not be detected but may exist at a rate roughly 10 times that of the LoBALs and so there may be ~ 50 FR-II HiBAL objects hiding in the lower redshift range in DR3. The expected number from naive statistics is ~ 150 , so HiBAL quasars may have a similar deficit in the low redshift sample. There appears to be a real dearth of FR-II–BAL objects, too small by an order of magnitude or more at high redshift and by a factor of at least ~ 4 at low redshift.

To account for their small numbers, either FR-II–BAL quasars are somehow selected against in DR3 – and all other quasar surveys – or there is some physical mechanism which

suppresses one characteristic when the other is present. Any selection effect at work would have to discriminate against quasars with combined FR-II–BAL properties, but not against quasars showing just one of these two phenomena; such a selection effect is difficult to imagine.

Evidence that there is a physical effect, however, which inhibits a quasar from simultaneously expressing FR-II and BAL properties is shown in Figure 3. For the population of eight FR-II–BALs, there is a significant anti-correlation between radio-loudness as measured by R^* and the strength of broad absorption features measured by the balnicity index, BI. The Spearman rank correlation coefficient for this sample is -0.714 with a significance level of 95.5%, regardless of whether R^* is corrected for reddening local to the quasar. If just the 5 LoBAL objects are considered, the correlation is perfect, using the higher BI for J1457+0426 uncorrected for FeII absorption, dropping to -0.700 (89%) for the corrected value. Given the vagaries of computing balnicities, the high significance of the FR-II–LoBAL correlation in this small sample could be fortuitous, but the trend of lower absorption with higher radio power is clear. In addition, this anti-correlation provides at least circumstantial evidence that the majority of these objects are correctly identified as being FR-II sources because summing the radio flux from the two sources nearest a radio-emitting BAL quasar would not produce such a strong effect simply by chance. For comparison, we also plot the FIRST BAL quasar sample from Becker et al. (2000); these objects use a different blue optical band (photographic 103a-O) for deriving R^* and are uncorrected for internal reddening, but such effects amount to only $0.1 - 0.2$, typically. The FR-II–BAL quasars define the upper envelope of the ordinary FIRST radio-selected BAL objects. These radio-emitting BAL quasars also have an anti-correlation between radio-loudness and BAL strength: the correlation coefficient is -0.435 , and significance level of 97.9%. This is entirely due to the HiBAL quasars; opposite to the FR-II–BAL quasar behavior, the ordinary LoBAL objects show no correlation of radio-loudness with balnicity, while the HiBAL quasars alone have a correlation of -0.747 with a significance of 99.8%.

In considering the origin of J1016+5209, Gregg et al. (2000) suggested that it is perhaps a rejuvenated BAL quasar – an ordinary FR-II source which has recently accreted material, thus explaining the presence of well-developed radio lobes and simultaneous BAL spectral features. While this could happen in any particular case, the anti-correlation of BAL strength with radio-loudness in FR-II–BAL sources (Figure 3) argues that there must be a physical mechanism which suppresses one property in the presence of the other. This trend provides strong support for the view that the BAL phenomenon is an evolutionary phase in the life of quasars, rather than merely the result of orientation to our line of sight. In the prevailing “unification through orientation” picture of quasars, the two phenomena are not obviously linked and so in the absence of contrived theoretical hypotheses for the observed

anti-correlation between the strength of broad absorption and the brightness of radio emission (either as FR-II or core emission), one should observe the statistically-expected number of quasars which exhibit both properties.

An alternative interpretation is that BALs result from a relatively early phase in the evolution of a quasar during its emergence from a thick shroud or cocoon of dust and gas (Voit, Weymann, & Korista 1993; Hamann, Korista, & Morris 1993; Egami et al. 1996). This evolutionary picture offers a natural explanation for the rarity of FR-II–BAL quasars: Radio emission, particularly the emergence of radio jets to create FR-II sources, is frustrated by the obscuring BAL shroud until the quasar can boil away enough of the material through radiation pressure. This alternative to the unification picture has been supported by findings based on FIRST radio BAL quasars (Becker et al. 2000; Gregg et al. 2000) and other radio studies of BAL quasars (Barvainis & Lonsdale 1997). In the cocoon-emergence model, the anti-correlation of BAL strength and radio-loudness is easily explained, perhaps even necessary.

The correlation between black hole mass and host galaxy bulge luminosity (Ferrarese & Merritt 2000; Gebhardt et al. 2000) has spurred recent advances in detailed modeling of quasar evolution which provide a theoretical foundation for this picture. Hopkins et al. (2005) develop merger-driven models in which quasars spend most of their accreting lifetimes, $\sim 10^8$ yrs, buried by obscuring material, emerging as visible luminous objects for only the final 10% of their existence, $\sim 10^7$ yrs. Though not elaborated in Hopkins et al. 2005, the interpretation of BAL quasars as an evolutionary stage can be equated to the transition period between totally obscured and highly luminous in the Hopkins model. Perhaps such refinements could be incorporated explicitly in the gas physics of future models. Given that $\sim 15\%$ of quasars exhibit BALs, the BAL phase in this model would last $\sim 10^6$ yrs.

These observational and theoretical considerations predict that BAL phenomena should preferentially be seen in the early stages of massive black hole mergers, though BALs may also result from minor merger episodes which might fuel quasar energetics (new or renewed) without significantly increasing the mass of the central black hole. Limited evidence does suggest that LoBAL quasars especially are associated with merger activity (Canalizo & Stockton 2001). Systematic high resolution optical and radio imaging of BAL quasars – FR-II–BALs in particular – could explore this possibility.

In principle, the statistics of FR-II–BALs provide some constraints on the timescale during which both phases can coexist in a single object, which would be an indicator of how long it takes a quasar to develop its radio flux output and evaporate BAL clouds. Estimates of FR-II lifetimes are uncertain but range from 10^6 to 10^8 years (O’Dea 2002), depending on the method used to obtain the estimate, and the actual range may easily be this large,

implying that the radio structures can long outlive the original quasar activity, including any early BAL phase. Because the dual FR-II–BAL phase appears to be under-represented by an order of magnitude in the general quasar population, the overlap FR-II–BAL period probably cannot exceed 10% of the BAL lifetime, or 10^5 yrs. The large deficit of FR-II–HiBAL quasars implies that the FR-II–HiBAL phase endures for an even shorter time, perhaps down by another factor of 10.

The relative rarity of FR-II–HiBALs compared to FR-II–LoBALs and the location of FR-II–HiBALs at relatively low balnicities (Figure 3) suggest that the evolution is from LoBAL to LoBAL+FR–II emission to a very brief HiBAL+FR–II period to radio emission from a typical BAL-free quasar. HiBALs are relatively more common than LoBALs by a factor of ~ 8 in the general population, but our present sample suggests roughly the opposite case for FR-II–BALs; the FR-II–HiBAL period must be very short-lived to explain the very small numbers of such objects. At this juncture, however, it is not at all certain that HiBALs and LoBALs are sequential evolutionary phases. It is possible that they are separate but similar manifestations of quasar behavior and LoBAL clouds somehow are more tolerant of radio activity. If absorbing clouds are being rapidly destroyed in their radio-loud environments, then BAL features in these hybrid objects are perhaps the most variable of any BAL quasars and so might be excellent candidates for spectroscopic monitoring. Any changes may provide direct measurements of how conditions in BAL clouds evolve as they dissipate as well as quantitative constraints on the conditions in the centers of quasars.

6. Summary

We have identified 6 quasars, 5 from the SDSS DR3 and one from the FIRST Bright Quasar Survey, which exhibit properties of FR–II radio sources and BAL quasars, bringing to 8 the number of known FR-II–BAL quasars; these objects constitute a relatively rare class of quasar. The rarity of the class and the observed anti-correlation between the strength of BALs and radio power can be explained naturally by the evolutionary picture in which the BAL phenomenon occurs in a relatively early phase as the quasar turns on and is breaking free of a shroud of enveloping gas and dust, probably the also the source of material being accreted by the massive black hole which powers the quasar output. The signature lobes of FR–II sources can form only after enough of the enshrouding material dissipates under the effects of the strong quasar radiation field, permitting the emergence of radio jets. The very small number of HiBAL objects with FR emission suggests that FR-II–HiBALs are much rarer, implying that the FR-II–HiBAL phase is particularly short. In the unification-through-orientation model of quasar behavior, there is no such simple explanation for the

observed properties of radio-emitting BAL quasars. Because they are in a rapidly evolving phase, the FR-II–BAL quasars may provide an opportunity to detect and measure changes in the properties of absorbing material around quasars, perhaps revealing more details of the general nature of infalling and outflowing stuff in the vicinity of a massive black hole.

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Table 1. FR-II–BAL Quasar Photometry

α	δ	z	u	g	r	i	z	$S_{1.4\text{GHz}}^{\text{a}}$	Type
00 43 23.43	−00 15 52.6	2.798	19.86	18.73	18.45	18.19	18.12	167.4	HiBAL
01 48 47.61	−08 19 36.3	1.679	19.60	19.18	18.89	18.43	18.36	81.2	LoBAL
09 52 32.32	+02 57 28.5	1.356	18.16	17.76	17.43	17.29	17.23	11.4	LoBAL
10 16 14.26	+52 09 15.7 ^b	2.455	21.63	20.55	19.55	19.22	18.82	185.2	HiBAL
11 41 11.62	−01 43 06.7 ^c	1.267	18.45	18.04	17.66	17.62	17.54	252.0	LoBAL
14 08 06.21	+30 54 48.7	0.837	18.08	17.79	17.38	17.33	17.19	26.1	LoBAL
14 47 07.41	+52 03 40.1	2.062	18.25	18.02	17.73	17.43	17.18	44.4	HiBAL
14 57 29.63	+04 26 55.8	1.420	23.07	21.24	20.47	18.88	18.58	4.0	FeLoBAL

^aTotal flux density from NVSS (Condon et al. 1997)

^bFIRST J101614+520915, the original FR-II–BAL quasar (Gregg et al., 2000)

^cLBQS 1138-0126, the second known FR-II–BAL quasar (Brotherton et al., 2002)

Note. — Optical photometry from SDSS, corrected for Galactic extinction

Table 2. FR-II—BAL Quasar Derived Properties

Object	M_g	$\log L_{1.4\text{GHz}}$	Size ($''$)	Size (kpc)	Core/Lobe (1.4 GHz)	$\log(R^*)^a$	BI (km/s)
J0043 – 0015	–26.44(–26.78)	34.1	15	117	0.09	2.9 (2.7)	1073
J0148 – 0819	–24.91(–25.57)	33.4	40	343	0.07	2.8 (2.5)	2645
J0952 + 0257	–25.82(–26.28)	32.4	69	585	0.06	1.4 (1.3)	8433
J1016 + 5209 ^b	–24.41(–25.80)	34.1	45	370	0.04	3.8 (3.0)	2401
J1141 – 0143 ^c	–25.50(–25.93)	33.6	21	177	0.04	2.9 (2.7)	900
J1408 + 3054	–25.38(–25.47)	32.3	216	1653	0.16	2.2 (1.6)	5977
J1447 + 5203	–26.53(–27.10)	33.3	37	311	0.11	2.1 (1.8)	911
J1457 + 0426	–22.44(–25.09)	31.9	19	159	< 0.18	2.4 (1.0)	9205 (3596) ^d

^aDerived from NVSS radio core+lobe flux and g magnitude corrected for Galactic reddening; quantities in parentheses are further corrected for extinction local to the quasar.

^bFIRST J101614+520915, the original FR-II–BAL quasar (Gregg et al., 2000)

^cLBQS 1138-0126, the second known FR-II–BAL quasar (Brotherton et al., 2002)

^dThe BI for J1457+0426 is given before and (after) correction for FeII absorption.

Note. — Derived quantities assume $H_0 = 71 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and $q_0 = 0.5$. Quantities in parentheses corrected for intrinsic extinction; see text for explanation.

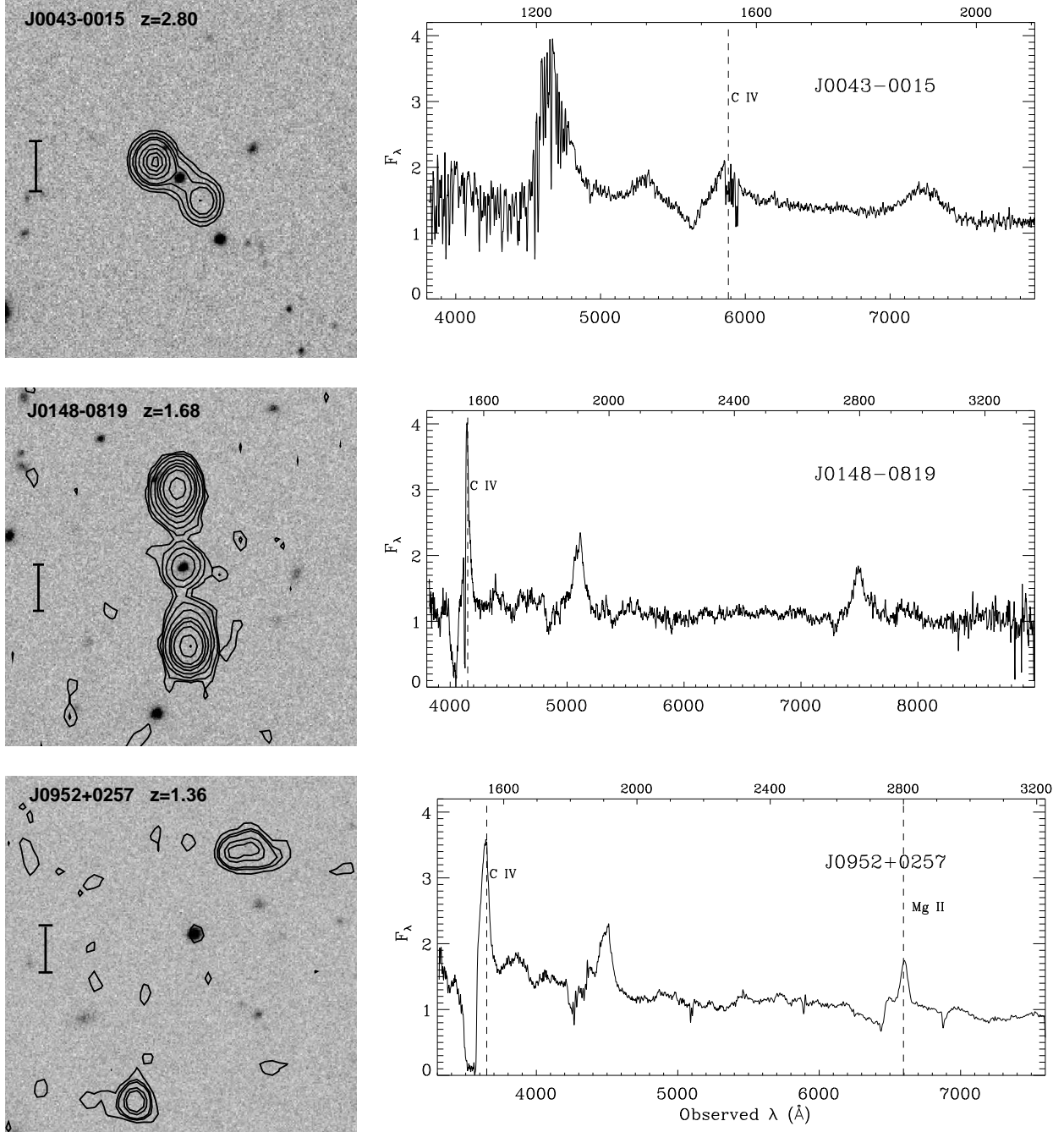


Fig. 1.— **Left panels:** SDSS *r*-band images of the FR-II-BAL quasars; FIRST survey radio contours overlaid. The vertical bars show the angular size of 100 kpc at the redshift of each quasar, typically 12". The two lowest redshift objects are shown at twice the scale of the others to include the large radio structures. **Right panels:** SDSS spectra used to identify the BAL nature of the quasars, except for the spectra of J0952+0257 and J1408+3054 which are from the Kast Spectrograph on the Lick 3m.

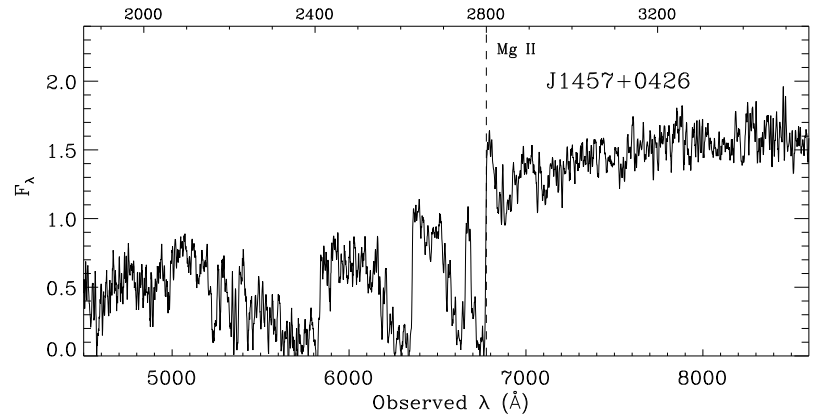
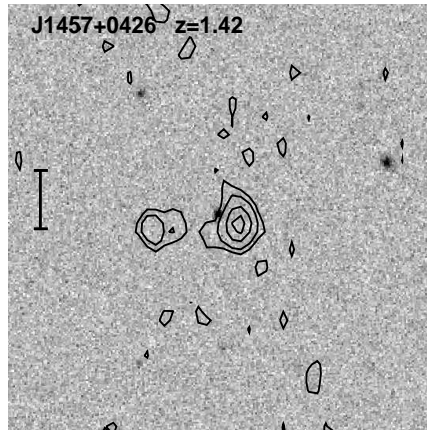
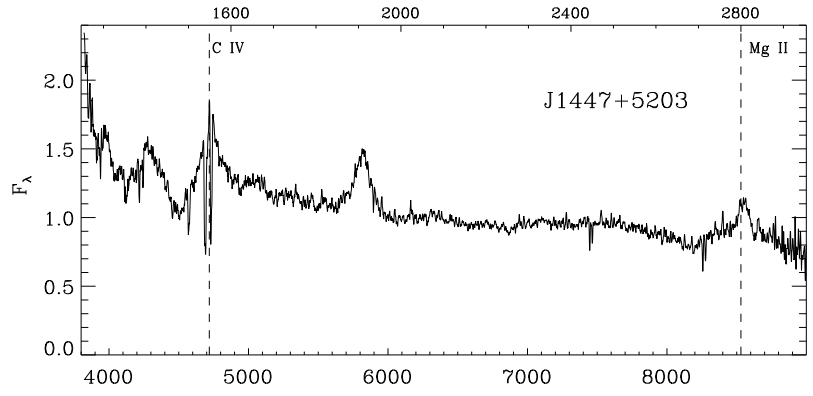
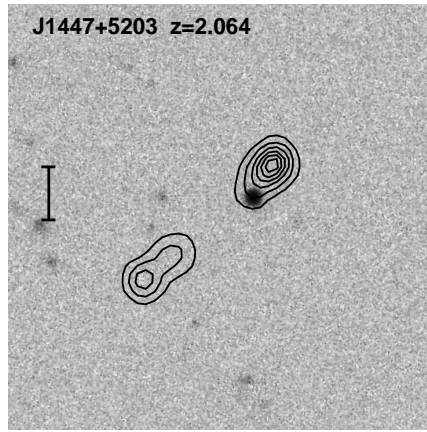
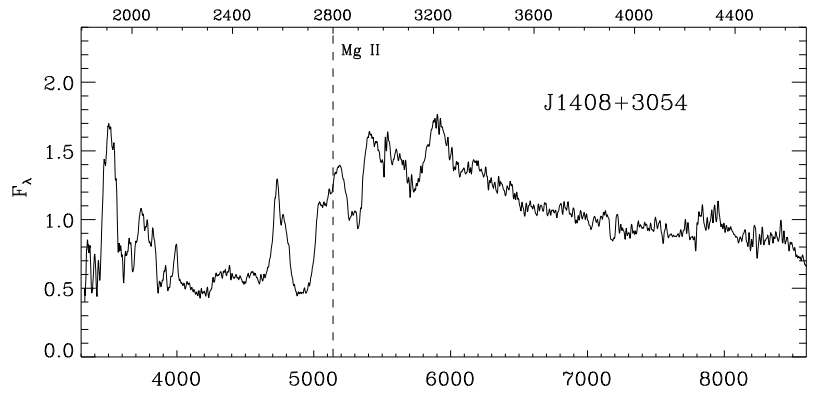
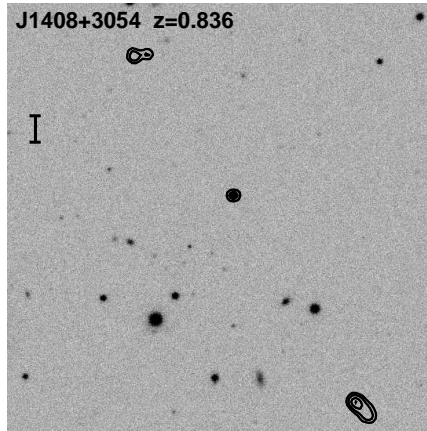


Fig. 2.— cont'd

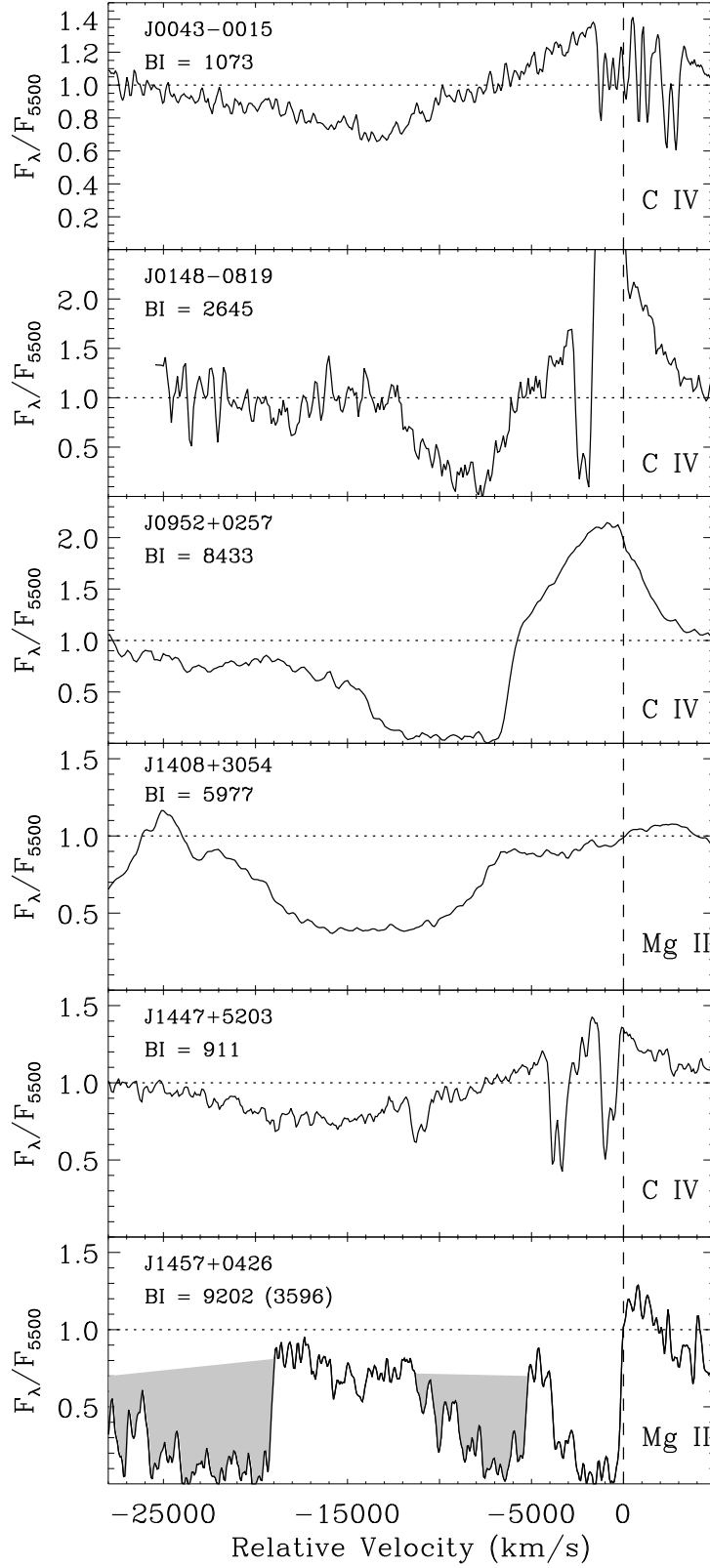


Fig. 3.— Close-up of the spectral regions from which the balnicity index is measured; J1408+3054 and J1457+0426 measurements are made using the Mg II region because C IV at these redshifts is in the ultraviolet. The spectra have been normalized and the continuum shape has been removed by dividing by a low order cubic spline. The BI for J1457+0426 is given before and (after) correcting for the Fe absorption (shaded regions).

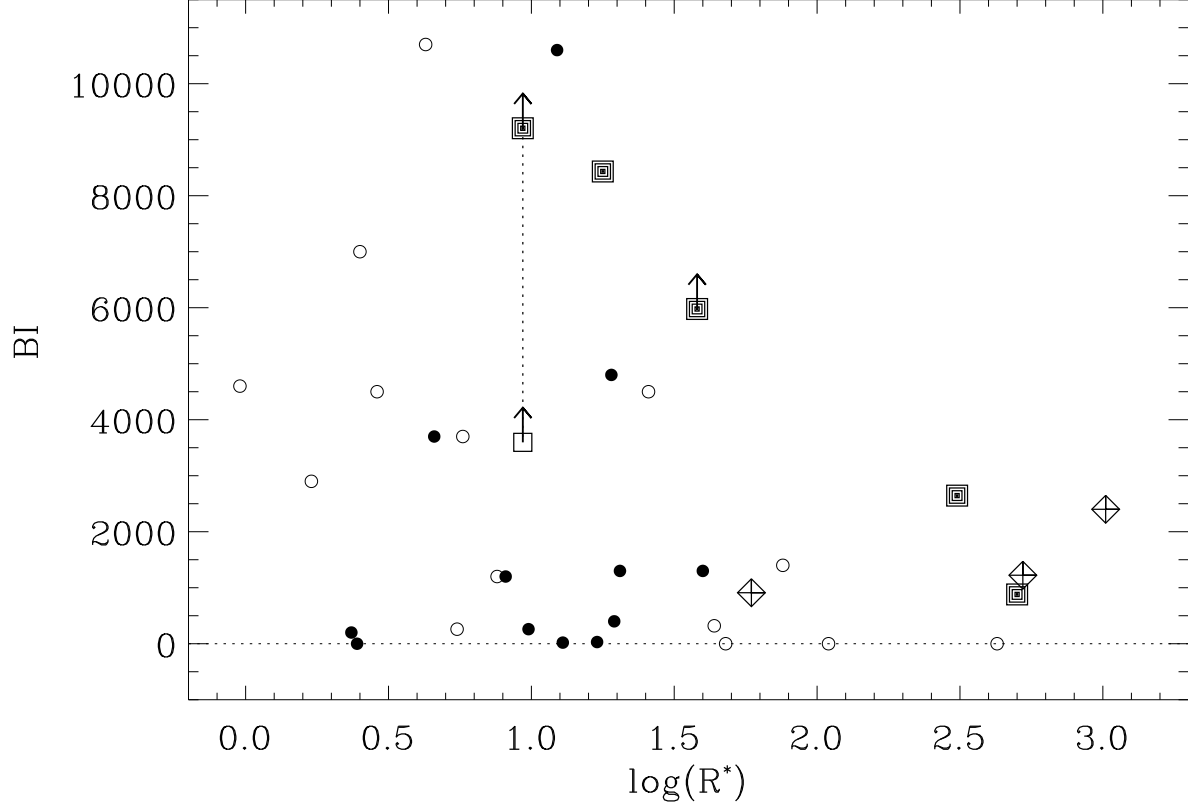


Fig. 4.— BAL strength, as quantified by the “balnicity index,” compared to the radio-loudness parameter R^* , corrected for reddening (see text). The filled squares are the five FR-II-LoBAL quasars; the positions of J1457+0426 before and after correction for the metastable Fe absorption are connected by a dotted line. J1408+3054 and J1457+0426 are plotted with upward arrows because their BIs have been measured from Mg II, which usually exhibits lower absorption than C IV. The crossed diamonds are the 3 FR-II-HiBAL quasars. Small circles are the radio-selected BAL quasar sample from Becker et al. 2000); filled are LoBALs, open are HiBALs. The FR-II-BALs are more extreme objects in both parameters and not only form an envelope containing the more common radio-emitting BALs, but exhibit a significant anti-correlation between radio-power and the prominence of broad absorption lines. This anti-correlation is stronger for the FR-II-LoBAL quasars alone.